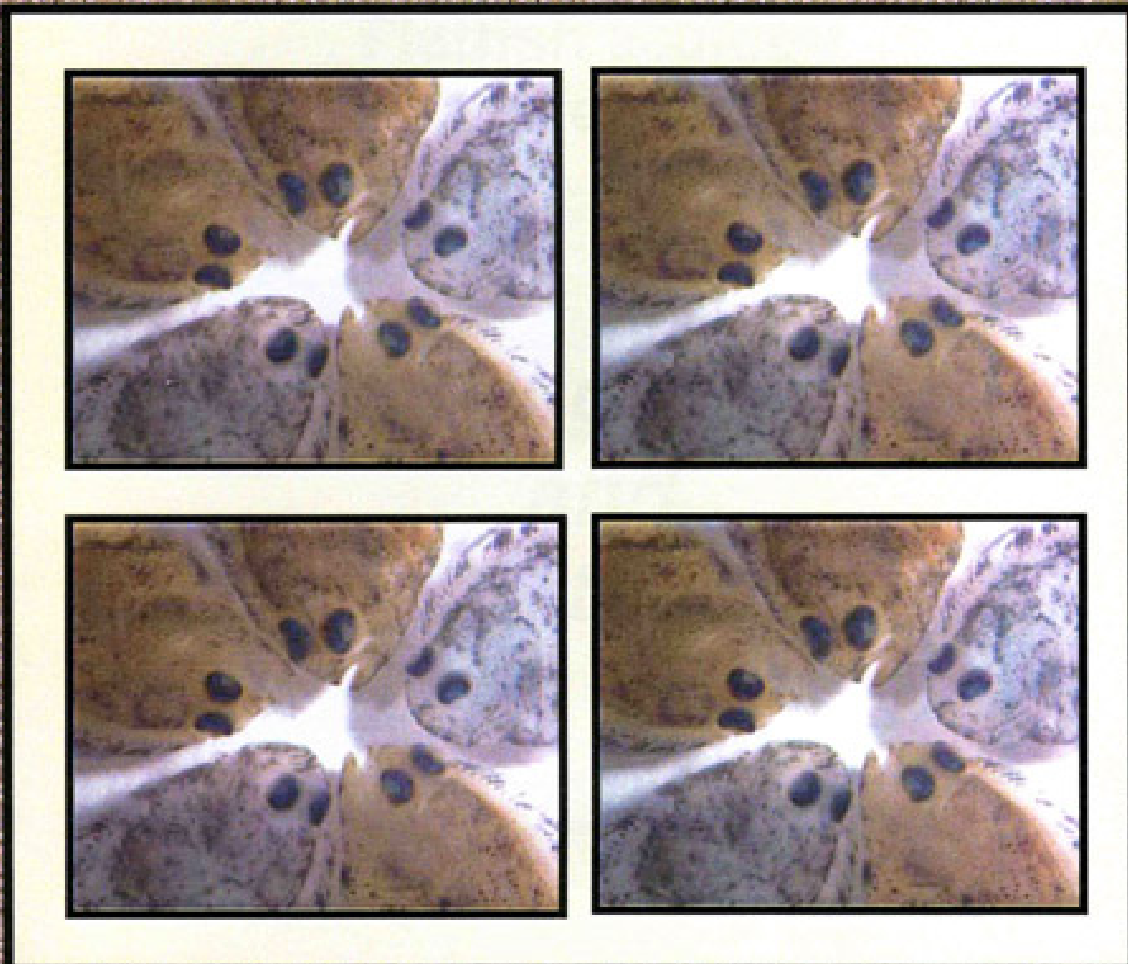
Flatfish Biology Conference



December 10-11, 2002

Westbrook, Connecticut

Northeast Fisheries Science Center Reference Documents

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Flatfish Biology Conference

December 10-11, 2002, Westbrook, Connecticut

by Conference Steering Committee: Renee Mercaldo-Allen (Chair)[1], Jay Burnett[2], Anthony Calabrese[1], Donald Danila[3], Mark Dixon[1], Penelope Howell[4], Ambrose Jearld[2], and Chris Powell[5]

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Eighth in a series of Flatfish Biology Conferences

U.S. DEPARTMENT OF COMMERCE
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Northeast Fisheries Science Center
Woods Hole, Massachusetts

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American Fisheries Society

Flatfish Biology Conference

December 10-11, 2002, Water's Edge Resort, Westbrook, Connecticut

Oral Presentations

Tuesday, December 10th

8:00 a.m. **Registration/Coffee, Continental Breakfast**

8:45 a.m. Welcome and Introduction

Renee Mercaldo-Allen
Anthony Calabrese
National Marine Fisheries Service
Northeast Fisheries Science Center
Milford, CT

John Boreman, Director
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, MA

Session I

Penny Howell, Chair
Connecticut Department of Environmental Protection
Fisheries Division, Old Lyme, CT

9:00 a.m. All-*trans* Retinoic Acid Stimulates Pigment Development in Summer Flounder

Michael Baron
University of New Hampshire, Department of Zoology,
Institute for the Development and Evolution of Wet Animals,
Durham, NH

9:20 a.m. Spatial and Temporal Patterns of Hogchoker (*Trinectes maculatus*) Reproduction in the Delaware Bay Estuary

Christina M. Hodgson, Stephen G. Piotrowski, Kenneth W. Able, and Thomas M. Grothues
Rutgers University Marine Field Station, Tuckerton, NJ

9:40 a.m. Global Patterns of Species Richness for Flatfishes (Order *Pleuronectiformes*)

Thomas A. Munroe
National Marine Fisheries Service, Northeast Fisheries Science Center,
National Systematics Laboratory, Smithsonian Institution, Washington, D.C.

10:00 a.m. Stock Structure of Yellowtail Flounder off the Northeastern United States
Steve Cadrin
National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole Laboratory, Woods Hole, MA

10:20 a.m. **Break/Coffee/Refreshments**

Session II

Donald J. Danila, Chair
Dominion Nuclear Connecticut, Inc., Millstone Environmental Laboratory
Waterford, CT

10:50 a.m. Examining the Decline of Narragansett Bay Winter Flounder
Allison DeLong and Jeremy Collie
University of Rhode Island, Graduate School of Oceanography, Narragansett, RI

11:10 a.m. Optimal Release Strategies for Winter Flounder Stock Enhancement
Elizabeth A. Fairchild and W. Huntting Howell
University of New Hampshire, Department of Zoology, Durham, NH

11:30 a.m. Metamorphosis in Summer Flounder: Manipulation of Rearing Salinity to Synchronize Settling Behavior, Growth and Development
Steven Gavlik and Jennifer L. Specker
University of Rhode Island, Graduate School of Oceanography, Narragansett, RI

11:50 a.m. **Hosted Buffet Lunch**

Session III

Ambrose Jearld, Chair
National Marine Fisheries Service
Woods Hole, MA

1:10 p.m. Active Sulfate Secretion by the Intestine of Winter Flounder, *Pseudopleuronectes americanus*
Ryan M. Pelis[1] and J. Larry Renfro[2]
[1]Mount Desert Island Biological Laboratory, Salisbury Cove, ME, and [2]University of Connecticut, Department of Physiology and Neurobiology, Storrs, CT

1:30 p.m. The Trophic Ecology of Northwest Atlantic Flatfishes: A Case Study of George's Bank
Jason S. Link[1], Michael J. Fogarty[1], Karen Bolles[2], Cheryl G. Milliken[3], and Rich W. Langton[4]
[1]National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole Laboratory, Woods Hole, MA, [2]Marine Research Institute, Reykjavik, Iceland, [3]Massachusetts Division of Marine Fisheries, Pocasset, MA, [4]Buccoo Reef Trust, Scarborough, Tobago

1:50 p.m. Tidal Rhythms in Winter Flounder

Beth Phelan
National Marine Fisheries Service, Northeast Fisheries Science Center, James J. Howard Marine Sciences Laboratory, Highlands, NJ

2:10 p.m. Winter Flounder Mortality on an Estuarine Nursery Ground: A Preliminary Analysis of Coarse and Fine-scale Habitat Patterns

John P. Manderson[1], Jeff Pessutti[1], Patricia Shaheen[1], and Francis Juanes[2]
[1]National Marine Fisheries Service, Northeast Fisheries Science Center, James J. Howard Marine Sciences Laboratory, Highlands, NJ and [2]University of Massachusetts, Department of Natural Resources Conservation, Amherst, MA

2:30 p.m. **Refreshment Break**

Session IV

Mark Dixon, Chair
National Marine Fisheries Service
Milford, CT

3:00 p.m. Use of Video to Assess Juvenile Winter Flounder Densities and Habitats

Lisa Meng[1], Giancarlo Cicchetti[1], and Steve Raciti[2]
[1]U.S. Environmental Protection Agency, Atlantic Ecology Division, Narragansett, RI and [2]Vassar College, Poughkeepsie, NY

3:20 p.m. The Genetic Stock Structure of Larval and Juvenile Winter Flounder (*Pseudopleuronectes americanus*) in Connecticut Waters of Eastern Long Island Sound and Estimations of Larval Entrainment

Joseph F. Crivello[1], Donald J. Danila[2], Ernesto Lorda[2], Milan Keser[2], and Edward F. Roseman[2]
[1]University of Connecticut, Departments of Physiology and Neurobiology and Marine Sciences, Storrs, CT and [2]Dominion Nuclear Connecticut, Inc., Millstone Environmental Laboratory, Waterford, CT

3:40 p.m. Formation of Year-class Strength of the Niantic River, CT Winter Flounder Stock-When and Where Variation Occurs and Suggestions on How and Why

Donald J. Danila and Edward F. Roseman
Dominion Nuclear Connecticut, Inc., Millstone Environmental Laboratory, Waterford, CT

4:00 p.m. **Poster Set-up**

5:00 p.m. **Hosted Mixer and Poster Session**

Wednesday, December 11

8:15 a.m. **Registration/Coffee/Continental Breakfast**

Session V

Jay Burnett, Chair
National Marine Fisheries Service
Woods Hole, MA

9:00 a.m. The Smallmouth Flounder, *Etropus microstomus*, in Narragansett Bay: Looks Like They are Here to Stay
Grace Klein-MacPhee[1], Aimee Keller[1], Dennis Erkan[2], and Michael Scherer[3]
[1]University of Rhode Island, Graduate School of Oceanography, Narragansett, RI, [2]Rhode Island Department of Environmental Management, Division of Fish and Wildlife, Jamestown, RI, and [3]Marine Research Inc., Falmouth, MA

9:20 a.m. Review of the Ecology of Winter Flounder in Narragansett and Mt. Hope Bays: Why the Decline?
Rodney A. Rountree, Brian Rothschild, Lou Goodman, Wendall Brown, Yalin Fan and Liuzhi Zhao
University of Massachusetts at Dartmouth, School for Marine Science and Technology, New Bedford, MA

9:40 a.m. Sand Shrimp, *Crangon septemspinosa,* Predation on Juvenile Winter Flounder: Effect of Temperature on Predator Functional Response and Foraging Behavior
David L. Taylor
University of Rhode Island, Graduate School of Oceanography, Narragansett, RI

10:00 a.m. Can the Predator Pit Hypothesis Explain the Retarded Recovery of Southern New England Winter Flounder Stocks?
Saul B. Saila[1] and Ernesto Lorda[2]
[1]University of Rhode Island, Graduate School of Oceanography, Narragansett, RI, and [2]Dominion Nuclear Connecticut Inc., Millstone Environmental Laboratory, Waterford, CT

10:20 a.m. **Break/Coffee/Refreshments**

Session VI

Chris Powell, Chair
Rhode Island Division of Environmental Management
Jamestown, RI

10:40 a.m. Winter Flounder Essential Fish Habitat (EFH) Conservation Recommendations
Michael Ludwig
National Marine Fisheries Service, Habitat Conservation Division, Milford, CT

11:00 a.m. Genetic Stock Identification and Mass-balance Modeling Determine Contribution of Niantic River Winter Flounder Larvae to Power Plant Entrainment
Edward F. Roseman[1], Donald J. Danila[1], Ernesto Lorda[1], and Joseph Crivello[2]
[1]Dominion Nuclear Connecticut, Inc., Millstone Environmental Laboratory, Waterford, CT and [2]University of Connecticut, Departments of Physiology and Neurobiology and Marine Sciences, Storrs, CT

11:20 a.m. The Enigmatic Deep-water Witch Flounder of the Mid-Atlantic Bight

Jay Burnett and Susan Wigley
National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole Laboratory, Woods Hole, MA

11:40 a.m. Culture of Atlantic Halibut (*Hippoglossus hippoglossus*) in Offshore Net Pens

W. Huntting Howell, Michael Chambers, and Nathan Rennels
University of New Hampshire, Department of Zoology, Durham, NH

12:00 p.m. **Hosted Buffet Lunch**

1:00 p.m. **Adjourn Meeting**

Poster Session

Tuesday, December 10, 5:00 p.m.

Squamation, Pigmentation and Asymmetry in Summer Flounder

David M. Boynton and Jessica A. Bolker
University of New Hampshire, Department of Zoology, Institute for the Development and Evolution of Wet Animals, Durham, NH

The California Halibut as an Aquaculture Candidate: A Comparison to Other Flatfish

Douglas E. Conklin[1], Raul H. Piedrahita[2], Jean-Benoit Muguet[1], German E. Merino[2, 3], and Margarita Cervantes-Trujano[1, 2]
[1]University of California, Department of Animal Science, Davis, CA, [2]University of California, Department of Biological and Agricultural Engineering, Davis, CA, and [3]Universidad Catolica del Norte, Departamento de Acuicultura, Coquimbo, Chile

Initial Evidence of Vertical Migration of Winter Flounder (*Pseudopleuronectes americanus*) in a New Jersey USA Estuary

Mary Carla Curran[1], Robert J. Chant[2], Kenneth W. Able[3], and Scott M. Glenn[2]
[1]Savannah State University, Marine Science Program, Savannah, GA, [2]Rutgers University, Institute of Marine and Coastal Studies, New Brunswick, NJ, and [3]Rutgers University, Marine Field Station, Institute of Marine and Coastal Studies, Tuckerton, NJ

The Contribution of Southern Flounder and Summer Flounder to the Recreational Fishery of the Southeastern USA

Mary Carla Curran and Donna E. McDowell
Savannah State University, Marine Science Program, Savannah, GA

Mortality of YOY Winter Flounder Held on Newark Bay Sediment: Some Unplanned Observations

Andrew F. J. Draxler and Kristina M. Salvati
National Marine Fisheries Service, Northeast Fisheries Science Center, James J. Howard Marine Sciences Laboratory, Highlands, NJ

Abundance, Distribution, and Condition of Hogchokers (*Trinectes maculatus*) in the Hudson River Estuary April-September, 2002
Ivan Ferron and Chris Chambers
National Marine Fisheries Service, Northeast Fisheries Science Center, James J. Howard Marine Sciences Laboratory, Highlands, NJ

Temporal Changes in Behavior of the Blackcheek Tonguefish, *Symphurus plagiusa*
Jody L. Frost and Mary Carla Curran
Savannah State University, Marine Science Program, Savannah, GA

Site Fidelity Patterns of Sub-legal Summer Flounder in Virginia Waters from Angler-assisted Tagging Program Data, 2000-2002
Jon A. Lucy[1] and Claude M. Bain, III[2]
[1]Virginia Sea Grant Marine Advisory Program, Virginia Institute of Marine Science, College of William and Mary, Gloucester Pt., VA, and [2]Virginia Saltwater Fishing Tournament, Virginia Marine Resources Commission, Virginia Beach, VA

Embryonic and Larval Staging of Summer Flounder, *Paralichthys dentatus*
Gabriela M. Martinez and Jessica A. Bolker
University of New Hampshire, Department of Zoology, Institute for the Development and Evolution of Wet Animals, Durham, NH

Seasonal Changes in Blood Chemistry of the Yellowtail Flounder, *Limanda ferruginea*
Renee Mercaldo-Allen, Margaret A. Dawson, Diane Kapareiko, and Catherine A. Kuropat
National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT

Winter Flounder Stock Enhancement
Ben Morgan[1] and Michael Scherer[2]
[1]Llennoco, Inc., Chatham, MA, and [2]Marine Research Inc., Falmouth, MA

Winter Flounder (*Pseudopleuronectes americanus*) Spawning Areas in New Haven Harbor
Jose J. Pereira, Ronald Goldberg, and Paul Clark
National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT

The Feeding Behavior of Atlantic Halibut, *Hippoglossus hippoglossus*
Gwynne Schnaittacher and David Berlinsky
University of New Hampshire, Department of Zoology, Durham NH

Histological and Biochemical Comparison of Skin Development in Normal and Malpigmented Summer Flounder
Amy Van Cise, Tanya F. Hakala, and Jessica A. Bolker
University of New Hampshire, Department of Zoology, Institute for the Development and Evolution of Wet Animals, Durham, NH

Skeletal Anomalies in Offshore Species of Flatfish, American Plaice: A Comparison with Winter Flounder
John Ziskowski
National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT

Abstracts
Oral Presentations

All-*trans* Retinoic Acid Stimulates Pigmentation Development in Summer Flounder*

Michael Baron

University of New Hampshire, Department of Zoology
Institute for the Development and Evolution of Wet Animals
Durham, NH 03824

Dietary carotenoids and Vitamin A are thought to be important factors in the development of flounder pigmentation. However, supplementation of these compounds has yielded mixed results (Kanazawa, 1993, Takeuchi *et al.,* 1995). Retinoic acid (RA) is a hormone derived from carotinoids and Vitamin A. RA has been used to stimulate pigmentation development in the Japanese flounder, *Paralichthys olivaceus* (Miwa and Yamano, 1999, Haga *et al.,* 2002). This study examined the effect of RA on pigmentation development in summer flounder, *Paralichthys dentatus*. Larvae were immersed in 5 and 10 nM concentrations of RA for a period of 10 days preceding metamorphosis. Fish were reared for an additional 20 days following treatment. Nearly all fish in the study developed normal ocular side pigmentation. Fish in the control group also expressed normal development on the blind side. However, over 60% of the fish in the treatment groups expressed partial or total pigmentation of the blind side. These results support a role for retinoic acid in the pigmentation development of flounder.

*Supported by New Hampshire Sea Grant #111381 to Jessica Bolker.

Spatial and Temporal Patterns of Hogchoker (*Trinectes maculatus*) Reproduction in the Delaware Bay Estuary

Christina M. Hodgson, Stephen G. Piotrowski, Kenneth W. Able, and Thomas M. Grothues

Rutgers University, Marine Field Station
Tuckerton, NJ 08087

Hogchokers (*Trinectes maculates*) are one of the dominant fishes in Delaware Bay based on a seven-year (1996-2002) survey of intertidal and subtidal creeks. In order to learn more about their basic life history, specimens were collected during May to November from 1999-2002 to determine spatial and temporal patterns of reproduction. Seven marsh creek systems representing lower (12-18 ppt), middle (5-7 ppt) and upper (0-5 ppt) bay along the New Jersey side of Delaware Bay were sampled monthly with replicate tows of a 4.9-meter otter trawl (6-mm cod end mesh). Initial observations based on length frequency distributions and spatial/temporal patterns show potentially mature individuals (85-140-mm TL) frequenting the lower bay during spawning season where salinity is highest. Intermediate sizes (60-85 mm TL) were found further upstream while abundance of young-of-year (YOY) (35-60 mm TL) peaks were found where salinity is the lowest. The differentiation of size classes along a salinity gradient is consistent with the Dovel (1969) model. Verification by calculating a monthly Gonadosomatic Index (GSI) over three years helps define the reproductive pattern of hogchokers in response to seasonal shifts of environmental factors such as temperature and salinity.

Global Patterns of Species Richness for Flatfishes (Order Pleuronectiformes)

Thomas A. Munroe

National Marine Fisheries Service
Northeast Fisheries Science Center
National Systematics Laboratory
Smithsonian Institution
Washington, DC 20560

Comparisons of species richness estimates reveal interesting patterns regarding the ecological biogeography of flatfishes. Within all regions, flatfishes are most diverse where extensive continental shelves with complex habitats are located in shallow water. Generally, diversity of marine flatfishes increases along continental shelves from polar to equatorial waters, with maximum diversity of flatfish assemblages usually occurring on tropical and subtropical continental shelves within each ocean. Flatfish diversity is also high at continental shelf areas where components from different faunal provinces intermix. Lower than expected diversity is noted on continental shelf regions where cold-water currents and upwelling occur. In all oceans, but especially in the West Pacific, flatfish diversity is lower at insular compared with continental locations at the same latitude. Within each geographic region, continental islands (usually larger with heterogeneous soft-sediment habitats) generally support higher numbers of flatfish species than do oceanic islands (usually smaller with less habitat complexity) located in the same region. Among four tropical marine regions, the highest diversity of flatfishes occurs in the western Pacific (125 species compared with 45 in the western Atlantic, 43 in the eastern Pacific and only 38 species in the eastern Atlantic). Diversity of flatfishes in northern temperate and boreal regions is greater than that of corresponding areas in the southern hemisphere. Far fewer species are known from temperate and boreal areas in the Atlantic and eastern Pacific oceans compared with those from the western Pacific at comparable latitudes.

Stock Structure of Yellowtail Flounder off the Northeastern United States

Steve Cadrin

National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole Laboratory
Woods Hole, MA 02649

This interdisciplinary study evaluated spatiotemporal patterns of abundance, geographic variation in growth and maturity, larval transport, morphometry, and genetics of the yellowtail flounder in the northeastern United States. The results suggest that yellowtail flounder found on the principal U.S. fishing grounds should be managed as separate stocks, despite genetic homogeneity. Two "harvest stocks" of yellowtail flounder have significantly different patterns of abundance and biomass over time, with a boundary from southwest Georges Bank to Nantucket. Geographic patterns of size and proportion mature at age indicate two "phenotypic stocks" of yellowtail flounder, with a boundary along the northern edge of Georges Bank to Nantucket. Therefore, yellowtail from the southern New England fishing grounds form a separate harvest stock than those on the Georges Bank or Cape Cod grounds, and Cape Cod yellowtail are a separate phenotypic stock than those on Georges Bank or off southern New England. No significant differences were detected between southern New England and Mid-Atlantic yellowtail, or between those from the Cape Cod grounds and the Gulf of Maine. Inferred larval movement reveals a passive southwest drift along the continental shelf. Morphometric analysis showed sexual dimorphism and significant difference between yellowtail from U.S. waters and those sampled off Newfoundland, but little morphometric variation among U.S. areas. Genetic analysis also found little variation among U.S. samples. U.S. yellowtail flounder resources appear to comprise a single genetic stock, but significant variation in critical life history attributes and different patterns of abundance over time suggest that three fishery management units exist: southern New England-Mid Atlantic, Georges Bank, and Cape Cod-Gulf of Maine.

Examining the Decline of Narragansett Bay Winter Flounder

Allison Delong and Jeremy Collie

University of Rhode Island
Graduate School of Oceanography
Narragansett, RI 02882

The Narragansett Bay winter flounder population has experienced a severe decline in abundance over the last two decades, as evidenced by catches in the Rhode Island Department of Environmental Management, Division of Fish and Wildlife and University of Rhode Island, Graduate School of Oceanography standardized trawl surveys. Although regional populations (southern Massachusetts, Long Island Sound, Rhode Island Sound) of winter flounder have also experienced declines, they do not appear to have been as severe as those observed in Narragansett Bay and several of these other populations have begun to recover under strict fishing regulations. The principle objective of this study was to use field data to describe the decline of winter flounder in Narragansett Bay and to find evidence of those factors that have led to the decline and have kept it from rebuilding at the rates experienced by regional populations. We first present a comparative analysis of several regional populations: Narragansett Bay, Mt. Hope Bay, southern Massachusetts, Long Island Sound and Niantic River, CT. To do this, we estimated the abundance of and mortality rates between 7 life stages: egg, larval, young-of-the-year (YOY) spring, YOY fall, age-1 spring, age-1 fall, and age-2 spring. We then examined environmental variables that may have affected winter flounder abundance and mortality rates within Narragansett Bay. The variables considered included age-class abundance, year, water temperature, precipitation, fishing mortality, seal abundance, double-crested cormorant abundance, chlorine discharge from wastewater treatment facilities, dissolved oxygen, salinity and power plant flow and heat load. Stepwise regression and regression tree analyses were performed to determine those environmental variables that best explain changes in stage-specific mortality rates.

Optimal Release Strategies for Winter Flounder Stock Enhancement

Elizabeth A. Fairchild and W. Huntting Howell

University of New Hampshire
Department of Zoology
Durham, NH 03824

As part of a program to assess the feasibility of winter flounder, *Pseudopleuronectes americanus*, stock enhancement, optimal release size, site, season, and condition of caged cultured juvenile winter flounder were evaluated.

To determine optimal release size, the predator-prey size relationship between winter flounder and the green crab, *Carcinus maenas*, was examined. The number of flounder killed per day was significantly higher (31%) in winter flounder < 20-mm compared to all other larger fish size classes (4-8% killed/day). Additionally, these fish were attacked at a faster rate than any other fish size class. These results suggest that only flounder > 20-mm should be released.

Field studies were conducted in three potential release sites in the Great Bay Estuary during 1999-2001 to determine optimal release site and season. Optimal site selection was based on growth and survival of caged cultured fish in relation to water temperature, prey availability, and sediment composition. Optimal season was selected based on the temporal distribution, abundance, and sizes of wild flounder, and their primary prey and predators. Within the estuary, Broad Cove was chosen as the optimal release site due to high fish growth rates coupled with the high prey availability and sandy substrate.

Although predators were equally abundant throughout the summer months, early summer was determined as the most appropriate time for winter flounder releases because prey were most abundant and wild flounder sizes were similar to the optimal release size for cultured fish. The condition of the cultured flounder was studied through a series of experiments to evaluate their vulnerability to predation based on behavior, color, and substrate preference. Cultured winter flounder reacted differently than wild flounder when exposed to cues from a potential predator and were significantly more vulnerable to predation by birds, regardless of fish color. Additionally, cultured flounder selected sediments consisting of small grains and of colors matching their own pigment.

Prior to any winter flounder enhancement effort, pilot-scale releases should be conducted to test release strategies.

Metamorphosis in Summer Flounder: Manipulation of Rearing Salinity to Synchronize Settling Behavior, Growth and Development*

Steven Gavlik and Jennifer L. Specker

University of Rhode Island, Graduate School of Oceanography
Narragansett, RI 02882

In the aquaculture of summer flounder (*Paralichthys dentatus*), the inherent variation in growth and settling behavior during metamorphosis may lead to cannibalism and necessitate increased labor due to size grading. Our goal was to use an environmental salinity change to synchronize settling behavior and produce a uniformly sized cohort of juvenile summer flounder. Early metamorphic summer flounder (Age: 41 dah) were exposed to either a 5-day fluctuating (30-20-30-20-30 ppt; "Flux") or a single (30-20 ppt; "Low Salinity") drop in rearing salinity. The Flux group was reared at 30 ppt while the Low Salinity group remained at 20 ppt until sampling at 61 dah. A control (continuous 30 ppt) was used for comparison. For all treatments, the initial n=60 fish/tank, and 3 tanks/treatment. Settling behavior in the control was prolonged, with the Peak Settlement Interval (PSI; defined as the interval beginning on the day the first 20% settled until the day 80% had settled) requiring 8 days. Settling behavior was synchronized by the Low Salinity treatment, with the PSI reduced to 5 days. The Flux treatment negatively affected settling behavior with the PSI increased to 10 days. By 61 dah, average fish size was increased by the Low Salinity treatment (19.3 ± 0.5 mm), but not the Flux treatment (17.2 ± 0.4 mm), compared to the control (17.6 ± 0.5 mm). Developmental stage at 61 dah was significantly increased in the Low Salinity treatment (3.2 ± 0.1) in comparison to the Flux (2.9 ± 0.1), but not the control (3.1 ± 0.1). However, the Low Salinity treatment reduced variance in development. To confirm the positive effects of the Low Salinity treatment, a second experiment was performed. A single salinity drop (30-20 ppt) at 37 dah (Low Salinity2) was compared to a control (continuous 30 ppt). In this experiment, the Low Salinity2 treatment did not synchronize settling. The PSI for the Low Salinity2 treatment was 14 days while the control was 13 days. Additionally, by 58 dah, average fish length (16.8 ± 0.2 mm) and developmental stage (2.9 ± 0.1) in the Low Salinity2 treatment was not significantly different than the control (16.1 ± 0.2 mm; 2.8 ± 0.1). Variance in both length and developmental stage at 58 dah in the Low Salinity2 treatment was not significantly reduced compared to the control. Percent survival was unaffected by treatment in both experiments. In aquaculture, the effective synchronization of settling behavior and growth through environmental manipulations may reduce the labor costs associated with size grading. A fluctuating salinity regime is not effective in this regard. A single drop in rearing salinity may result in synchronization of settlement and development and an increase in size. Future work will consider combining a single salinity drop (to 20 ppt) treatment with our previously reported thyroid hormone manipulation treatment (Gavlik *et al*., 2002).

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*This work was supported by Rhode Island Sea Grant, under NOAA Grant No NA16RG1057.

Active Sulfate Secretion by the Intestine of Winter Flounder, *Pseudopleuronectes americanus**

Ryan M. Pelis[1] and J. Larry Renfro[2]

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Marine teleosts are hypoosmotic to their surrounding environment and must continuously drink seawater to avoid dehydration. It is widely accepted that water uptake across the marine teleost intestine is driven by active absorption of monovalent ions (Na^+ and Cl^-). However, intestinal transport of divalent ions ($SO_4$2-, Mg^{2+}, and Ca^{2+}) has been less intensively studied. In this study, $SO_4$2- transport by winter flounder (*Pseudopleuronectes americanus*) intestine was characterized in Ussing chambers. Under short-circuited conditions and 1 mM $SO_4$2- on both sides, net active $SO_4$2- secretion (blood-to-lumen) occurred (7.42 ± 0.63 nmoles x cm^{-2} x hr^{-1}). Treatment with NaCN (10 mM) or ouabain (0.1 mM) inhibited net secretion indicating dependence on metabolism and the plasma membrane Na^+ gradient. Luminal treatment with the anion exchange inhibitor 4, 4'-diisothiocyanatostilbene-2-2'-disulfonic acid (DIDS, 0.2 mM) also inhibited net secretion. Removal of Cl^- alone, and Cl^- and HCO_3- together from the luminal bath solution reduced net SO42- secretion. Removal of HCO_3- alone stimulated net secretion. Sulfate uptake into foregut brush-border membrane vesicles was stimulated by a trans-Cl^- gradient (in>out), and unaffected by a trans-HCO_3- gradient (in>out). Short-circuiting with K^+, in=out, and valinomycin had no effect on Cl^--stimulated $SO_4$2- uptake suggesting electroneutral exchange. These data indicate that the winter flounder intestine actively secretes SO42- by exchanging for luminal Cl^-. This process may function in water absorption and in the maintenance of plasma $SO_4$2- homeostasis.

*Supported by NSF.

The Trophic Ecology of Northwest Atlantic Flatfishes: A Case Study of Georges Bank

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The Georges Bank fish community has undergone drastic changes over the past several decades, including dramatic declines in the abundance of key flatfish species. Many of these declines have been attributed to intensive fishing pressure. Flatfish are both directly susceptible to fishing gears and indirectly susceptible to the impact of those gears on the ocean bottom. Thus, Georges Bank flatfishes play multiple roles as populations highlight the need to understand the role of these fish as predators, competitors, and prey. We present estimates of relative abundance for major flatfishes from research surveys, which demonstrate that even with a recent recovering trend for a few species due to area closures, most flatfishes are far from their levels of historical abundance. Because flatfishes serve as a major energy pathway for conversion of benthic production into a form suitable for consumption by higher predators and humans, we then examined the diet of nine major flatfishes from this ecosystem including primarily polychaete- crustacean feeding or piscivorous species, with one echinoderm specialist. From this information, we assess the magnitude of predation by flatfish on other components of the food web. Additionally, we evaluate the degree of competition among the flatfishes and between the flatfishes and other fish species via diet overlap, spatial overlap, interaction coefficient estimates, and cross-correlation of population abundances. Skates are the primary competitor of flatfishes in this ecosystem and have the potential to competitively depress some flatfish populations. Finally, we explore the implications of flatfish trophic ecology with respect to different flatfish population recoveries and how the Georges Bank ecosystem may function in the future.

Tidal Rhythms in Winter Flounder

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Knowledge of endogenous rhythms provides important life history information that helps us understand the dynamic nature of habitat selection. Activity rhythms of winter flounder under controlled condition in the laboratory were observed and compared with the distribution pattern of winter flounder at high and low tides in the field. In the laboratory, all sizes of winter flounder tested (20-69 mm TL) exhibited high activity levels following high tide. Winter flounder in the field were more abundant across certain depths that shifted with the tide. It is hypothesized that winter flounder movement patterns allow them to take advantage of feeding opportunities and to avoid predation.

Winter Flounder Mortality on an Estuarine Nursery Ground: A Preliminary Analysis of Coarse and Fine Scale Habitat Patterns

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In the Navesink River/Sandy Hook Bay estuarine system, New Jersey winter flounder larvae are known to settle throughout the estuary but spatial settlement patterns are rapidly modified by postsettlement mortality and/or emigration. In this study, we performed chronological tethering experiments and trammel net surveys at both coarse and fine spatial scales to test the hypothesis that predation mortality was responsible for the alteration of the settlement pattern.

Coarse scale experiments showed that survivorship for tethered flounder (20-40 mm standard length) during the settlement period (late April - mid May) was variable but generally high throughout the estuary. However, as the season progressed, survival declined in the Navesink River and was lower in the region than in Sandy Hook Bay. Patterns of predator abundance and diets from trammel net collections suggest that summer flounder, searobins, and blue crabs were probably responsible for flounder mortality.

Fine scale experiments performed in the Navesink River during the post-settlement period (June -July) to examine habitat effects showed that the survivorship of juveniles (40-60 mm SL) was significantly higher in shallow water (<50 cm) than in adjacent deep habitats (>150 cm) that lacked structural complexity and were less than 30 m apart. Summer flounder appeared to be important predators in the deeper water river habitats.

Our preliminary analyses of coarse scale patterns suggest that predation pressure on juvenile winter flounder may be higher upstream in the river during the post-settlement period. However, analysis of fine scale habitat differences show that shallow water habitats including those that lack structural complexity may serve as critical refugia reducing predator encounter rates in geographic regions where predators and prey overlap.

Use of Video to Assess Juvenile Winter Flounder Densities and Habitats

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We used a digital video camera mounted to a 1-m beam trawl together with an attached continuous recording YSI sonde and a GPS unit to quantify juvenile winter flounder densities and fish habitat in Narragansett Bay, RI. The YSI sonde measured temperature, salinity, dissolved oxygen, depth, turbidity, and chlorophyll a. We hypothesized that human-induced habitat alteration would correlate with a decrease in juvenile winter flounder densities. We sampled true-random points derived from digitization of the entire shoreline of the West Passage and the Providence River. At each random point, the camera/beam trawl/YSI unit was deployed at the water's edge, then towed out perpendicular to shore for 50-100 m, depending on the amount of macroalgae present. We sampled 80 transects from June-July 2002 and captured 603 fish representing 23 species. Winter flounder made up 60% of the catch, followed by grubby at 22%. Contrary to our expectations, juvenile winter flounder densities were greater at sites with more anthropogenic influence. Densities were highest at the head of the bay, near the city of Providence and in other semi-enclosed areas with high chlorophyll a values. When random locations were broken down into eight habitat types (beach, marsh, cobble beach, rip-rap, rock, industrial, marina and macroalgae), densities were highest near rip-rap, industrial areas, and marinas. These areas tended to be near the head of the bay or near harbors with high levels of nutrients and chlorophyll a.

The Genetic Stock Structure of Larval and Juvenile Winter Flounder (*Pseudopleuronectes americanus*) in Connecticut Waters of Eastern Long Island Sound and Estimations of Larval Entrainment

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The winter flounder (*Pseudopleuronectes americanus*) is one of a number of coastal American flatfish that face intense fishery pressure and thus has been the focus of management efforts. This species has experienced dramatic declines in abundance over the past three decades with concomitant decreases in commercial and recreational fishing landings. The genetic stock structure of winter flounder larvae in Long Island Sound has not been previously characterized. Stage 1 (yolk-sac) and 2 (pre-flexion) larvae were collected from several locations in Long Island Sound known to be nursery areas for winter flounder in the spring of 2001. The genetic variations among larvae were characterized through the use of 6 microsatellite loci that had been previously reported to be highly polymorphic and heterozygous in winter flounder. The gene frequency differences were used to characterize population structure. Substantial genetic differences were seen among the putative source populations. These genetic differences appeared to be geographically based and provide evidence of genetically distinct spawning populations that appear to be temporally stable. These differences were used to characterize the most likely sources of winter flounder larvae entrained at the Millstone Power Station as well as settled juvenile winter flounder collected in the Niantic River. Samples were classified to the most likely geographical source population through use of a neural net learning algorithm. A validation of these classification results was conducted using a re-sampling scheme based on a bootstrap methodology that led to estimations of the 95% and 99% confidence intervals. These results are discussed in the context of winter flounder management issues.

Formation of Year-class Strength of the Niantic River, CT Winter Flounder Stock -When and Where Variation Occurs and Suggestions on How and Why

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Formation of year-class strength in most of the marine fishes largely occurs during the larval and early juvenile stages, yet these phases of life history are often the least understood. Long-term ecological studies of winter flounder conducted at Millstone Power Station in Waterford, CT since the early 1980s have focused on the nearby Niantic River spawning stock and have afforded the means for examining changes in abundance at sequential developmental stages during early life history. Variable annual rates of mortality in early life history can result in large differences in abundance and, hence, in year-class strength at time of recruitment to the spawning stock. Changes in survival and abundance can often vary annually, indicating that complex processes affect recruitment and that these processes may also be different from year to year. From our studies, annual abundance data are available on the adult spawning stock and female egg production during the winter-spring spawning season, larvae of four developmental stages in the Niantic River and Bay during spring, settled age-0 juveniles in the river (and for 5 years in the bay) in summer, and older (ages-0 and 1) juveniles that disperse throughout our study area in fall and winter. We describe these data and note where critical changes in abundance and mortality have occurred during certain periods of early life history. Although our sampling has been relatively consistent for about two decades, allowing good annual comparisons to be made, we have only limited information on processes likely affecting mortality and abundance. Thus, mechanisms that affect survival and recruitment are largely limited to inferences made using results from studies completed elsewhere. However, our considerable information on winter flounder in conjunction with other data gathered during our studies and elsewhere enables us to suggest potential processes that affect the formation of winter flounder year-class strength in southeastern Connecticut.

The Smallmouth Flounder, *Etropus microstomus*, in Narragansett Bay: Looks Like They are Here to Stay

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The smallmouth flounder is a small flatfish found in near shore waters and estuaries ranging from Cape Cod to Cape Hatteras. The center of distribution appears to be the Chesapeake Bight, where they are one of the most numerous flatfish species collected in the ichthyoplankton. The eggs and larvae are fairly common off southern New England and Cape Cod, but were rare in Narragansett and Mount Hope Bay. Impingement data from the Brayton Point Power Plant in Mount Hope Bay, Massachusetts shows an increasing upward trend in smallmouth flounder numbers since 1985. Previous ichthyoplankton surveys in Narragansett Bay collected few smallmouth flounder, but a recent survey begun in June 2000 collected relatively large numbers of eggs and larvae. Sampling conducted in 1972-1973 showed no smallmouth flounder eggs and few larvae, but the eggs were not described until 1980. In 1990, no eggs and few larvae were collected. In the 2000 ichthoplankton collection, the eggs comprise 16.5% of the ichthyoplankton and were ranked second in abundance, and the larvae comprised 11%, also second in abundance over the summer and fall seasons. In 2001 and 2002, the smallmouth flounder continues to be a presence, the temporal occurrence is May-October and it is present at all stations in Narragansett Bay.

Review of the Ecology of Winter Flounder in Narragansett and Mt. Hope Bays: Why the Decline?

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Winter flounder abundances have experienced dramatic declines throughout the greater Narragansett Bay estuarine system, including within Mt. Hope Bay and the Sakonnet River. In Mt. Hope Bay in particular, the decline of winter founder has been suggested to be more severe than in other regions and is often attributed to the impact of the Bryton Point Power Plant. The major reason for this assertion is that the decline in Mt. Hope Bay was coincident with a large increase in the power plants cooling water intake and effluent in 1984. We have examined time trends in the abundance of winter flounder and other species from 11 different areas within the Narragansett Bay system based on trawl data collected by the Rhode Island Department of Environmental Protection from 1979-2001. Most areas exhibit decline patterns similar to that of Mt. Hope Bay. Mt. Hope Bay declines are not significantly greater than other comparable areas, and in fact are less than declines in Greenwich Bay and the Sakonnet River. A further examination of the spatial-temporal patterns in the greater Narragansett Bay reveal that shallow semi-enclosed areas have exhibited the greatest declines and that declines are stronger for juvenile size classes than for adults. These patterns suggest an overall shrinkage of winter flounder's distribution in the bay. We also examined spatial temporal patterns in the fish assemblage and find that the Narragansett Bay fish community has undergone a dramatic shift from benthic to pelagic species. This pattern is strongest in the shallow embayments (Greenwich Bay, Sakonnet River, Mt. Hope Bay, Wickford Harbor and upper Narragansett Bay), and weakest in the deep central bay and adjacent Rhode Island Sound areas. These patterns are consistent with community structure changes associated with eutrophication. We suggest that changes in the abundance of winter flounder and fish species assemblages in Mt. Hope Bay and greater Narragansett Bay over the last 25 years is symptomatic of widespread eutrophication.

Sand Shrimp, *Crangon septemspinosa*, Predation on Juvenile Winter Flounder: Effect of Temperature on Predator Functional Response and Foraging Behavior

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Predator-prey dynamics between the sand shrimp, *Crangon septemspinosa,* and juvenile winter flounder were examined in laboratory experiments to assess the joint effects of varying prey density and temperature on shrimp foraging behavior and mortality of flounder. The functional response of shrimp to six densities of flounder was determined at two temperatures (10 and 16 °C). Moreover, the behavioral mechanisms underlying the shrimp's functional response (encounters, attacks, captures, and handling time) were quantified with visual observations and compared to the foraging parameters predicted by continuous-time functional response models. Shrimp consumption rates increased significantly with increasing flounder density, irrespective of water temperature. At low flounder densities, however, significantly more flounder were consumed at 16 °C then at 10 °C. Analysis of proportional mortality of flounder across prey density revealed a positively density-dependent (sigmoidal) type-III functional response at 10 °C, and an inversely density-dependent (hyperbolic) type-II functional response at 16 °C. Based on model parameter estimates and visual observations of predator foraging behavior, differences in functional responses were attributed to increased shrimp activity (and encounters) at higher flounder densities and temperature. These findings indicate that shrimp are capable of driving young-of-the-year flounder populations to local extinction during warm water conditions.

Can the Predator Pit Hypothesis Explain the Retarded Recovery of Southern New England Winter Flounder Stocks?

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A plausible regulatory mechanism, based on predation of early life history stages of the winter flounder, *Pseudopleuronectes americanus*, was developed utilizing a reproduction curve with three equilibrium points. This type of reproduction curve was first suggested by Walters (1986), but apparently has not been tested with empirical data to date. We fitted a five-parameter curve to the relationship between spawning stock size and recruitment to Age 1 which contained three equilibria and which explained more than 80 percent of the variability in the data from the Niantic River, Connecticut. This type of relation can arise when a predator follows a sigmoid functional response in their consumption rates of early life history stages (larvae). If the predator population remains fixed over time, the prey stock may display a stable equilibrium at two stock sizes (S_1 and S_h). The stock size between these two stock sizes (S_u) is an unstable level from which the stock will collapse to a lower value or grow towards the high equilibrium value (S_h). Following the initial work of Taylor (this conference), the sand shrimp, *Crangon septemspinosus*, is implicated as a major predator of winter flounder at early life history stages. Using a segmented regression technique, we demonstrate that there is some coherence between the decline of the winter flounder stocks and the relative abundance of predators. We conclude that this work suggests that the predator pit region of the reproduction curve may account for the delayed recovery of southern New England winter flounder stocks.

Reference: Walters, C. 1986. Adoptive Management of Renewable Resources. Macmillan, New York.

Winter Flounder Essential Fish Habitat (EFH) Conservation Recommendations

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Throughout history, statutory laws have been enacted that unexpectedly create conflicts between government agency objectives. Over the last half-century, the conflicts between mandates that favor water resource development and environmental protection of those same waters have become evermore contentious. The focusing of legal intent to the point where they can occur, now, within a single agency has facilitated these mission conflicts. The passage of supplemental legislation in furtherance of either mandate has narrowed the focus and sharpened the conflict with the result that agencies are compelled to act against each other. The conflicts between the three resource agencies (US Fish & Wildlife Service [FWS], the National Oceanic and Atmospheric Administration / National Marine Fisheries Service [NMFS], the US Environmental Protection Agency [EPA]) and the US Army Corps of Engineers (Corps) are legendary. Today, as we move into the twenty-first century, the conflict between improving Port infrastructure by providing adequate access and the need to protect public trust resources living within the same waters has become a national concern. The conflict is embodied in time-of-year restrictions on dredging and disposal of sediment. Resolution of the matter is problematic because the objectives cannot be reconciled in mutual mandates or economic frameworks. For example, invocation of a seasonal window to protect aquatic resources may preclude a single, continuous dredging of a desired access channel. Valuation of the dredging and cost delays is possible, but valuing aquatic resource impacts is not an equally well-grounded practice.

Because winter flounder are unique in their spawning and early life stage characteristics, they tend to engender agency conflict and special note in EFH Conservation Recommendations. Through a series of serendipitous and focused investigations NMFS has come to be the source of much of the controversy. Species sensitivity, spawning concentration identification, and early life stage movements are the issues that have come to be the basis for negotiating resource protective objectives under the EFH program. Local knowledge of these matters is vital as are the advances made in dredging and our understanding of the impacts associated with it. Much of this interplay has taken place in the waters off the New England coastline. Today, NMFS routinely invokes seasonal constraints on any activities that might diminish winter flounder EFH from January to June.

Genetic Stock Identification and Mass-balance Modeling Determine Contribution of Niantic River Winter Flounder Larvae to Power Plant Entrainment

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Catch-per-unit-effort of winter flounder in assessment trawl surveys conducted in the Niantic River, CT has declined since the early 1980's. While the causes of this decline are speculative, the magnitude of the impact of entrainment by Millstone Power Station (MPS) on the Niantic River stock depends upon how many larvae originated from the Niantic River. Hydrodynamic modeling and tidal current drogue studies conducted in the 1970s and 1990s showed that much of the water entering MPS comes from Long Island Sound. Other winter flounder stocks are known to spawn east and west of the Niantic River and tidal studies indicated that winter flounder larvae from those sites entered Niantic Bay from Long Island Sound. In our study, mass-balance calculations were used to investigate whether the number of larvae entering Niantic Bay from the Niantic River could sustain the number of larvae observed in the bay during the period from 1984 through 2001. Further, we estimated the number of entrained winter flounder larvae originating from the Niantic River and compared these results with estimates derived from genetic stock analysis performed in 2001. The lowest percent entrainment attributed to the Niantic River winter flounder stock was observed in 1997, with 12.3% of 9.3 million larvae entrained originating from the Niantic River. The highest percent entrainment attributed to the Niantic River stock occurred in 1996, when 58.8% of the 30.4 million entrained larvae were determined to be of Niantic River origin. In 2001, mass-balance calculations and genetic stock analysis provided similar results, determining that 21.4% and 22%, respectfully, of the 80.7 million larvae entrained were of Niantic River origin. Both methods showed that peak fractional entrainment of Niantic River larvae occurred early in the spring. Together, these studies provide a validated characterization of the sources of winter flounder larvae entrained at MPS.

The Enigmatic Deep-water Witch Flounder of the Mid-Atlantic Bight

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The existence of a deep-water (greater than 366 meters) resource of witch flounder, *Glyptocephalus cynoglossus*, along the northeastern U.S. continental slope and adjacent abyssal plain is suggested by several lines of evidence including: 1) egg and larval distribution patterns; 2) by-catch rates in deep-water surveys for red crab (*Chaceon quinquedens*) and monkfish (*Lophius americanus*); and 3) various special deep-water studies conducted as far south as Virginia. Nothing is known regarding the abundance, biology, and production rates of these fish or their affiliation to witch flounder in shallower shelf waters. Recent opportunistic sampling at depths ranging from 367-914 meters has provided a limited number of samples for the preliminary estimation of growth and maturation rates. When compared to witch flounder of the shallower regions of the Gulf of Maine and Georges Bank, growth rates for deep-water fish were considerably lower and maturation occurs at a greater age. Differences in otolith morphology and length-weight relationships were also observed. Possible linkages of these deep-water witch flounder to other populations in the Northwest Atlantic are hypothesized.

Culture of Atlantic Halibut (*Hippoglossus hippoglossus*) in Offshore Net Pens

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The University of New Hampshire's Open Ocean Aquaculture Demonstration Project seeks to stimulate the development of commercial aquaculture in New England. Among the finfish species we have been working with, Atlantic halibut were selected because of their high market value and demand, tolerance to cold water, good growth rates and feed conversion ratios, disease resistance, and reduced availability from the wild fishery.

In May of 2001, 2000 juvenile halibut (30 g mean weight) were purchased from R&R Development Ltd. in Digby, Nova Scotia, and transferred to the UNH Coastal Marine Lab in New Castle, NH. Here, the fish were cultured to 100 g mean weight in a flow through seawater system. In October of 2001, the halibut were transferred to a 600 m^3 Sea Station cage located 14 km offshore in 52 m water depth. The cage was submerged 12 m below the ocean surface for grow-out. Fish have been fed (Shur Gain™ halibut diet) once per day at a rate of 3-4% body weight. Fish are being sampled once per month for survival, weight, and total length.

Survival has been excellent (>90%), and the current average weight of the fish is 456g. We expect to harvest them when they reach 1-2 kg, which should occur in the summer of 2003. The only difficulty we have encountered has been with fat cell necrosis syndrome ("sunburn") in some mal-pigmented fish maintained in a surface cage. Information gained from this initial growout experiment will hopefully further the development of halibut culture in New England.

Abstracts
Poster Presentations

Squamation, Pigmentation, and Asymmetry in Summer Flounder

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Flatfishes, such as the summer flounder (*Paralichthys dentatus*), provide unique opportunities to study the development of morphological asymmetry. We have examined left/right differences in squamation and pigmentation throughout early development in *P. dentatus*, documenting scale development and location in relation to age, size, and overall pigmentation pattern (normal, albino, or ambicolored). General patterns of scale development in *P. dentatus* resemble those in Japanese flounder (*P. olivaceus*; Seikai, 1980). In both species, scale development progresses from posterior to anterior, and from the center of each side out toward the dorsal and ventral margins, with squamation more advanced on the ocular side than on the blind. In malpigmented summer and Japanese flounder, pigmentation is associated with the degree of ctenoid scale development: dark pigmentation correlates with the presence of ctenii. Kikuchi and Makino (1990) noted that in ambicolored Japanese flounder (*i.e*., those with a partially dark blind side), pigmentation and ctenoid scales appear to "wrap" around the dorsal and ventral margins from the ocular to the blind side. We see the same pattern in ambicolored summer flounder. The association of scale type with pigmentation – ctenoid scales in dark areas of skin, and cycloid scales in light areas – appears essentially the same in summer as in Japanese flounder. However, our observations of radii, in all summer flounder scales we have examined, suggest that tentatively identified "cycloid" scales may actually represent primary (incompletely developed) ctenoid scales. This raises the question of whether there are any true cycloid scales in juveniles of this species.

The California Halibut as an Aquaculture Candidate: A Comparison to Other Flatfish

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Research into the culture of the California halibut, *Paralichthys californicus,* is comparatively new but has the advantage of building on information gathered for other flatfish aquaculture candidates. This presentation compares what information is available for the California halibut to that for other flatfish species. As with other flatfish, a combination of rotifers followed by enriched brine shrimp nauplii and some formulated feed were initially used for rearing California halibut larvae. The employment of a static green-water type system in the second season of research dramatically increased the numbers of larvae brought through metamorphosis. Substantial improvements in weaning were also made during the second year of the project in which weaning was achieved as early as 42 days, compared to over 100 days in the first year.

The characteristic morphology and behavior of metamorphosed flatfish offer a number of advantages to culturists. All the flatfish being considered for culture are temperate species but increases in growth rate are noted with limited increases in temperature. A summary of growth rates (Specific growth rate; SGR, %/day) for a number of flatfish species with notes on culture conditions and feed is presented. Work to date with the various flatfish species suggests, as with other marine species, a high requirement for dietary protein. Although lipid requirements have yet to be defined it is thought they will most easily be satisfied through the use of marine lipids. Conversely, meeting these requirements for protein and marine lipids undoubtedly will be expensive. Fortunately, in that these fish spend much of their time lying motionless on the bottom, food conversion should be particularly attractive. In addition, provision of inputs such as oxygen and removal of wastes should be less of a challenge that for actively swimming species. It appears that culture density of flatfish, as defined by coverage of the tank bottom, can be surprisingly high. Some species have been grown at densities over 100%, which necessitates the fish stack on top of each other. One other particularly interesting component of flatfish culture is the potential for various flatfish to be cultured in an environment of reduced salinity. This could allow culturists to move away from expensive coastal sites. Information available with regard to growth and survival of various flatfish species under reduced salinity conditions is summarized. While we are still in the process of researching many of the above culture components, work to date suggests that the California halibut has the potential to become one of a number of flatfish species that will be commercially cultured in the future.

Initial Evidence of Vertical Migration of Winter Flounder (*Pseudopleuronectes americanus*) in a New Jersey USA Estuary

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Our prior research indicated that coves near Little Egg Inlet, New Jersey are settlement areas for winter flounder (*Pseudopleuronectes americanus*), and that estuarine circulation patterns in this flood-dominated system supported the advection of larvae into these coves. The purpose of the present study was to determine the vertical distribution of larvae. We performed both surface and bottom plankton tows (bongo nets) synchronously with repeated Acoustic Doppler Current Profiler (ADCP) transects over the study area. Despite tidal currents approaching 2 m/s, our observations indicate that the temporal variability of larval abundances cannot be explained solely on horizontal advection. On average, more larvae (42-489.8/1000m^3) were collected at the bottom than at the surface (0-233.0/1000m^3). We always collected larvae at the bottom, but collected no larvae at the surface 31% of the time. These results, in conjunction with results from simultaneous 1-m plankton tows, indicate the importance of behavior in the advection of these larvae into settlement coves. Larvae that migrate to the bottom of the channel during the ebb may avoid being swept out the inlet and instead may move to the surface during the subsequent flood to find suitable settlement habitat within the estuary.

The Contribution of Southern Flounder and Summer Flounder to the Recreational Fishery of the Southeastern USA

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The Marine Recreational Fisheries Statistics Survey (MRFSS) program of the National Marine Fisheries Service (NMFS) is a national program designed to estimate marine recreational finfish total catch, and angler effort and participation. It consists of a voluntary intercept survey of fishermen upon completion of their fishing trip and provides information on species catch and associated lengths and weights. The purpose of the present study is to demonstrate the value of the MRFSS program in providing important data to fisheries biologists despite the relatively small number of fishes collected. Between 1997 and 2001, the combined catch of the summer flounder, *Paralichthys dentatus*, and the southern flounder, *Paralichthys lethostigma,* contributed up to 8% of the recreational total catch in North Carolina, 8.1% in South Carolina, 2.9% in Georgia, and 4% in eastern Florida. However, North Carolina was the only state in which summer flounder dominated the flounder catch. The contribution of flounder ranged from a low of 1.3% (GA, 1997) to a high of 8.1% (SC, 2000). In 1998, a 12-inch size restriction was placed on flounder and we investigated the impact of this regulation. Using only data provided by DNR in Georgia for southern flounder, there was a significant difference in the fish sizes collected over the years. In 1997, 42% of the fish were under 12 inches, but only 10% were undersized in 2001. This encouraging news indicates that recreational fisherman seem to follow guidelines regarding size restrictions.

Mortality of YOY Winter Flounder Held on Newark Bay Sediment: Some Unplanned Observations

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Young of the year winter flounder (*Pseudopleuronectes americanus*) from Sandy Hook Bay suffered unexpectedly high mortality (45% in seven days) when held on sediments from a shallow area (0.5 m MLW) of Newark Bay off Bayonne NJ. Fish were randomly allocated to tanks containing either clean sand or Newark Bay sediment for the purpose of generating treatment and control animals to competitive predation experiments. Tanks were well flushed resulting in a maximum dissolved oxygen concentration gradient of less than 6 μM (0.2 mg/L) from inlet to outlet. Mortality was minimal among controls on clean sand, but in the tank containing Newark Bay sediment some fish were found dead on top of sediment and many more had died while buried, suggesting the latter had not made an effort to escape the lethal conditions. The shallow depth (3 cm) of sediment employed and the measures taken to preclude hypoxia in the water suggest that constituents of Newark Bay sediment other than biogeochemicals were responsible for the mortality.

Abundance, Distribution, and Condition of Hogchokers (*Trinectes maculatus*) in the Hudson River Estuary, April – September 2002

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Hogchokers (*Trinectes maculatus*) are an abundant component of estuarine systems in the mid-Atlantic Bight. Despite their abundance, little is known about hogchoker biology and their trophic role in general. This study was undertaken to provide new information on aspects of abundance, movement, growth, and reproduction of hogchokers in the Hudson River estuary. Hogchokers were collected during monthly bottom trawl surveys of the Lower Hudson River estuary during the spring through autumn of 2002. Fish were collected during 5-minute tows of two otter trawl sets at each of 10 stations spanning from lower Manhattan (Battery) to Newburgh, New York. Abundances and location of captured young-of-the-year, older juveniles and adults were recorded. These fish were processed at the laboratory for body length and weight, gender, and liver and gonad weights. The liver and gonadal weights were used to compute hepatic-somatic and gonadal-somatic indices, respectively, in order to identify spawning time and to define the role that the liver might play in fish condition and reproductive effort. Results of this study will be compared with earlier results from the Hudson River and Delaware Bay.

Temporal Changes in Behavior of the Blackcheek Tonguefish, *Symphurus plagiusa*

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Blackcheek tonguefish, *S. plagiusa*, are abundant in shallow coastal waters and have insignificant value as a sport fish or for the commercial fishing industry. In order to assess the behavioral patterns of one of the least understood flatfishes, observations were performed over a 48-h period in a controlled environment. Individuals were caught via trawl, measured, and randomly placed in separate experimental chambers (84 x 43 x 34 cm) within 36 h of capture. Chambers contained 1 cm of clean graded sand and 10 cm of water (30^{o}C and 29 ppt at start of experiment). To determine if any diel or tidal rhythmicity existed, fish were observed in approximate 3-h intervals in correspondence with high, ebb, low, and flood tide. A light with a red filter was used at night to minimize disturbance. Diel activity was quantified by noting the percent of the tonguefish body covered by sediment. That, in conjunction with data regarding whether individuals changed orientation or changed location, was utilized to determine activity patterns. Preliminary results suggest that blackcheek tonguefish were more active at night as indicated by less sediment coverage and the fact that fish changed location frequently. Future studies will focus on whether interaction between tidal stage and light level affects tonguefish movement patterns.

Site Fidelity Patterns of Sub-legal Summer Flounder in Virginia Waters from Angler-assisted Tagging Program Data, 2000-2002

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Summer flounder, *Paralychthys dentatus*, ranks among the top finfish landed in both Virginia's commercial and recreational fisheries. Under the Summer Flounder Fishery Management Plan, incremental increases of recreational fishery minimum size limits in 2002 to 394 mm TL (VA's coastal fishery) and 444 mm TL (VA's Chesapeake Bay fishery), coupled with angler bag limits and 1-2 week mid-summer fishery closures, are contributing to rebuilding of the stock. Requiring anglers to release greater proportions of their catches also provided an opportunity to learn more about the distribution and habitat use patterns of 1-3 year old flounder through the Virginia Game Fish Tagging Program (VGFTP). Beginning in 2000 the VGFTP has tagged over 10,800 juvenile flounder (through July 2002; fish typically 279-381 mm TL). Approximately 900 recaptures have been reported (8 % return rate). Fish are tagged in the caudal peduncle musculature with a Hallprint T-bar tag (anchor-10-mm long; sheath 65-mm long), a tag having approximately100% retention and producing no significant tagging mortality (from 3-10 day cage trials with tagged fish). Most tagging, and subsequent recaptures, occurred at fishing piers, bridge-tunnel complexes, and jetties. At several locations in 2001, 7-15 multiple recaptures (2-5 recaptures of the same tagged fish) provided unique data showing that some fish remained in the vicinity of certain structure sites over significant periods of time, *i.e.*, May through July/August and September-November. For example, a fish was recaptured on three separate occasions at the same pier between June and August (serial periods at large of 32/44/and 67 days); similarly, a fish recaptured five times at the same pier demonstrated site fidelity over serial periods of 12/13/50/58/and 74 days. At another pier a tagged fish was recaptured three times at the site during September-November (serial periods of 2/19/and 64 days). Recaptures of fish tagged during one year and recaptured the next year also demonstrate some occurrences of year-to-year site fidelity, both for sites in lower Chesapeake Bay as well as sites around ocean inlets. Short and long distance movements of flounder have also been demonstrated. Recaptures of flounder tagged at the Chesapeake Bay mouth have occurred from off Cape May (NJ), Long Island Sound (NY), North Carolina, and South Carolina beaches, a general pattern observed in earlier VIMS studies (1987-89 and 1995-96).

Embryonic and Larval Staging of Summer Flounder, *Paralichthys dentatus**

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Summer flounder, *Paralichthys dentatus*, is an increasingly important aquaculture species in the U.S. Like most other marine fishes, however, its early development is poorly known, mainly due to the historical difficulty of obtaining pelagic embryonic and larval stages. The cooperation of a commercial hatchery has enabled us to prepare a detailed staging table for embryonic and larval development using large numbers of embryos of known ages reared under controlled conditions. Our staging scheme is designed to facilitate rapid assessment of developmental stage based on readily visible landmark features, while providing more detailed descriptions of the morphological differentiation of the jaw apparatus and digestive system. We divide development into two main periods, pre-hatching and post-hatching, each of which is further subdivided into discrete morphological stages. Pre-hatching stages (fertilization to hatching) are based loosely on Shardo's (1995) staging table for *Alosa sapidissima*; post-hatching stages (hatching to metamorphosis) are aligned with the staging table for Japanese flounder (*Paralichthys olivaceus*; Minami, 1982; Fukuhara, 1986). The appearance and increasing complexity of discrete morphological features provides a more reliable and less variable measure of development than do simple scalar measures such as length, width or age. This staging scheme should therefore facilitate accurate assessments of developmental stage, which are important both for a wide range of applied studies (for example on larval nutrition), and for basic descriptive and experimental research in this species.

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Seasonal Changes in Blood Chemistry of the Yellowtail Flounder, *Limanda ferruginea*

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Seasonal changes in blood chemistry and hematology were observed in yellowtail flounder, *Limanda ferruginea*, collected from the Northwest Atlantic. Variations in blood parameters appear to be regulated by seasonally-induced physiological and/or environmental factors. Plama osmolalities during the winter, spring and summer seasons were significantly greater than in the fall. Sodium concentrations peaked during the winter and declined during spring and fall. Potassium was highest in the summer and lowest during the winter. Calcium was significantly higher in fall than spring. Hematocrit was highest in the spring and lowest during the fall. Hemoglobin values were elevated during the winter and spring months and declined during the fall. This baseline collection of blood data may be useful in monitoring the health and condition of yellowtail flounder in nature or under aquaculture conditions.

Winter Flounder Stock Enhancement

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The decline of traditional ground fisheries gives urgency to aiding the crisis by augmenting indigenous populations with hatchery-reared fish. Winter flounder (*Pleuronectes americanus*) may be an excellent candidate for stock enhancement. From 1997 to the present, Llennoco, Inc. has been successfully spawning adult winter flounder, growing out juveniles and tagging winter flounder for stock enhancement. From 2000 to the present, Marine Research, Inc. has successfully transported, released and recaptured those hatchery-reared fish. Issues have been addressed and obstacles overcome in the process, particularly in the areas of maintaining broodstock, life support systems, food supply and distribution, monitoring systems, transportation methods, tagging, release and recapture. The hatchery methods utilized by Llennoco, Inc. have proven that it is economically and biologically feasible to produce millions of juvenile winter flounder at a reasonable cost. The procedures developed by Marine Research, Inc. have shown that the hatchery-reared winter flounder do survive following release in Plymouth and Duxbury Harbors. Recaptured individuals obtained by beach seine as much as 95 days post-release showed good growth rates and cage studies suggested that survival rates may be equal between tagged hatchery-reared fish and naturally occurring fish. Stomach content analyses showed that the diets of released hatchery-reared fish and wild fish were identical. As a result of these efforts, it appears that winter flounder may be used for large-scale enhancement program.

Winter Flounder (*Pseudopleuronectes americanus*) Spawning Areas in New Haven Harbor

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As part of a previous study in 1994, 24 gravid female winter flounder were fitted with acoustic transmitters and released in New Haven Harbor, CT prior to the spawning season. The transmitters sent out a unique numerical signal so that individual fish could be identified. We visited the harbor weekly during spawning season and systematically searched the harbor for tagged fish using a directional hydrophone. Areas where fish were found were thought to be potential spawning areas. Fish were frequently located in Morris Cove on the eastern side of the harbor and around the east breakwater. Using a benthic sled, we then sampled these areas in an effort to collect fertilized winter flounder eggs and to confirm the presence of spawning activity at the site.

Since only a few winter flounder eggs were collected in 1994, the same six sampling sites were sampled more intensively in 1997. Triplicate tows were conducted at each site approximately biweekly from February to the beginning of April. In 1999, four sites in the shallower areas of Morris Cove were sampled using the same protocol as for the six sites sampled in 1997. In total, over 1400 eggs were collected, 115 of which were winter flounder eggs. The greatest number of winter flounder eggs was collected in mid-March in both years. The observed distribution of winter flounder eggs indicates that the northern end of Morris Cove and the area adjacent to it and east of the main channel are spawning areas for winter flounder.

The Feeding Behavior of Atlantic Halibut, *Hippoglossus hippoglossus*

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Atlantic halibut, *Hippoglossus hippoglossus*, is currently being explored as an aquaculture candidate in coastal waters of northern New England. To gain a better understanding of the feeding requirements of this species, the following experiments were conducted.

The first experiment examined the effect of feeding frequency on growth, feed consumption and feed conversion ratio (FCR). Juvenile fish (20g; 20/tank) were reared at 13ºC in 140 l tanks in a closed recirculating system (n=three replicates/treatment) over an 84-day period. The fish were fed one, three and fives times daily over a 12-hour period under constant lighting. A significant difference in growth was observed between fish fed one and five times daily ($p < 0.05$). Fish fed once daily consumed significantly less feed during this study (731.7g) than those fed three or five times daily (856.3g and 888.7g, respectively). There was no significant difference in feed conversion ratio (FCR) among treatment groups.

A second experiment was conducted to determine if Atlantic halibut exhibit an increase in swimming activity prior to a scheduled feeding (Feeding Anticipatory Activity; FAA). The activity of the fish (n=10/group), entrained to one feeding per day, was monitored by video for 72-h periods. Video recordings of fish movement were digitized and converted to histograms for statistical analysis. Preliminary analysis did not confirm the existence of FAA under these experimental conditions. Additional feeding experiments are currently in progress.

Histological and Biochemical Comparison of Skin Development in Normal and Malpigmented Summer Flounder*

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We have applied two complementary techniques to document skin and pigmentation development in summer flounder: paraffin histology, which shows both general skin structure and the specific location of melanophores, and a biochemical (DOPA) assay that reveals melanophores at early stages of their differentiation. In newly-hatched larvae (stage A; Martinez and Bolker, 2002), the skin is not yet divided into distinct dermal and epidermal layers; this morphological distinction begins to appear at stage C, and is well developed by the onset of metamorphosis (stage F). No early melanophores are detectable by the DOPA assay at stage A, but scattered cells on both ocular and blind sides show a positive DOPA reaction by stage E (late premetamorphosis); this pattern continues through stage H (late metamorphosis). No DOPA-reactive cells are detectable at later stages. In metamorphosed larvae 50 days after hatching, a layer of melanin is present between the dermal and epidermal layers of ocular-side skin, but absent on the blind side. Scales and scale pockets, which extend deeply into the dermis, begin to develop by 75 days after hatching; melanin is localized mainly at the base of the epidermis on the ocular side. In juveniles (>60 mm), dermal melanophores gradually replace epidermal melanin as the primary basis of dark pigmentation on the ocular side, though some extracellular melanin remains in the epidermis. Malpigmented juveniles display the same skin structure and melanin distribution as normal individuals at the histological level; however, albino fish show typical blind-side morphology in ocular-side skin, and ambicolored fish have ocular-type skin and pigmentation on both sides of the body.

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Skeletal Anomalies in Offshore Species of Flatfish, American Plaice: A Comparison with Winter Flounder

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American plaice are a good choice as a sentinel species for habitat monitoring in the Gulf of Maine and Massachusetts Bay. They are widely distributed in deep water, their population is relatively stable, and they are susceptible to axial skeletal deformities which are readily imaged through X-ray analysis. Since 1992, plaice have been regularly collected on NEFSC groundfish cruises and brought to the Milford Laboratory for X-ray analysis where nine types of deformities have been documented: fusion of individual centra, complexed- vertebrae which have incompletely separated during embryogenesis, accessory processes, deformed centra, reduced centra, spinal curvature, reduced processes, and hyper-ossification.

X-ray analysis of a sample of 66 plaice collected in Massachusetts Bay near the Boston Effluent Outfall in spring 2002 revealed that 11 of 66 fish (16.6%) had vertebral deformities; the most common were fusion and complexed-vertebrae, which affected 7 of 11 fish. Eight of the 11 deformed plaice had evidence of hyper-ossification. Prevalence of deformities in the 2002 sample was compared with a similar sample collected during the fall of 1994 from Massachusetts Bay. It was also compared with axial skeletal deformities found on winter flounder from Boston Harbor and Georges Bank, collected during the period 1989-1995.